Benchmark for simplified geometry in CALET

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Geometry for Montecarlo simulations

Simplified geometry (pisa model)
- FLUKA
- No support structures for CHD, IMC and TASC implemented

Flight geometry (cad model)
- All the shapes, sizes and materials of the CALET CAD model extracted from EPICS

This presentation
LORENZO's presentation
Summary of CAD simulations

- **TASC total energy**: good agreement among the three simulations
- **IMC total energy**: as far as energy increases the shapes for EPICS distributions differ wrt G4 and FLUKA ones.
- **CHD total energy**: as far as energy increases the shapes for EPICS distributions differ wrt G4 and FLUKA ones

Possible explanations:
- Different implementation of some volumes of the CALET flight model in G4 and FLUKA wrt EPICS?
- Possible differences in the simulation of the backscattering particles?

If yes, simulation with Pisa model could reveal this problem showing a better agreement among the simulations, since the geometry is exactly the same.

If yes, the problem would persist also in simulations with the Pisa model.
Simplified Geometry Simulation

Software version
- GEANT4-09-06-patch-02; Physics lists: FTFP_BERT
- EPICS 9.167 (COSMOS 7.645) Pisa-distributed CALET model; Hadron interaction model: DPMJET-III
- FLUKA 2011.2c.0; Hadronic interaction model: DPMJET-III

Benchmark for GEANT4, EPICS and FLUKA:
- Electron and Proton @ 10, 10^2, 10^3, 10^4 GeV

Particle Generation:
- Normal Incidence
- Generated in 4x4 cm^2 on top of CHD in the centre of the detector

Quantities shown in this presentation:
- Total Energy deposition in CHD, IMC and TASC
- Lateral and Longitudinal profile in IMC and TASC
- High Energy Trigger Efficiency
ELECTRONS
Electron Benchmark

- TASC total energy: good agreement among the three simulations at all energies tested
- IMC total energy: quite large differences among the three simulations appear as far as energy increases
- CHD total energy: large differences among the three simulations appear as far as energy increases
- I'm going to show distributions @ 1 TeV and @ 10 TeV where discrepancies appear.
TASC - Total Energy Deposition by electron

**All e^- @ 1 TeV**

- **HET e^- @ 1 TeV**
  - Simulation BinMax Diff. (%)
    - GEANT4: 0
    - EPICS: 0
    - FLUKA: 0.2692

**All e^- @ 10 TeV**

- **HET e^- @ 10 TeV**
  - Simulation BinMax Diff. (%)
    - GEANT4: 0
    - EPICS: 0.2548
    - FLUKA: 0

**10 GeV**

- HE Trigger Efficiency @ 10 GeV:
  - GEANT4: 90.0%
  - EPICS: 89.87%
  - FLUKA: 89.34%

**100 GeV**

- HE Trigger Efficiency @ 100 GeV:
  - GEANT4: 99.81%
  - EPICS: 99.89%
  - FLUKA: 99.83%

**1 TeV**

- HE Trigger Efficiency @ 1 TeV:
  - GEANT4: 99.99%
  - EPICS: 99.98%
  - FLUKA: 99.99%

**10 TeV**

- HE Trigger Efficiency @ 10 TeV:
  - GEANT4: 99.66%
  - EPICS: 99.99%
  - FLUKA: 99.99%
TASC - Lateral Deposition by electron

**All e⁻ @ 1 TeV**

**All e⁻ @ 10 TeV**

**TASC Lateral Distribution Results:**

- **Good agreement at the centre (<5%)**
- **Max Difference on tails for EPICS wrt G4 ~15%**
- **Max Difference on tails for FLUKA wrt G4 ~12%**

Difference calculated as:

\[
\text{Diff} = \frac{\text{EpicS}}{\text{G4}} - 1
\]

\[
\text{Diff} = \frac{\text{Fluka}}{\text{G4}} - 1
\]
TASC – Longitudinal Deposition by electron

All $e^-$ @ 1 TeV

All $e^-$ @ 10 TeV

Difference calculated as:

$$\text{Diff} = \frac{\text{Epics}}{G4} - 1$$

$$\text{Diff} = \frac{\text{Fluka}}{G4} - 1$$

TASC Longitudinal Distribution Results:

- Good agreement at the maximum layer (~1%)
- Max Difference at low energy layers for EPICS wrt G4 ~17%
- Max Difference at low energy layers for FLUKA wrt G4 ~15%
IMC - Total Energy Deposition by electron

**All e⁻ @ 1 TeV**

- **HET e⁻ @ 1 TeV**

- **10 GeV**
  - Simulation BinMax Diff. (%)
  - GEANT4 0
  - EPICS 8.314
  - FLUKA 3.764

- **100 GeV**
  - Simulation BinMax Diff. (%)
  - GEANT4 0
  - EPICS -3.47
  - FLUKA -3.673

- **1 TeV**
  - Simulation BinMax Diff. (%)
  - GEANT4 0
  - EPICS 12.28
  - FLUKA 30.66

- **10 TeV**
  - Simulation BinMax Diff. (%)
  - GEANT4 0
  - EPICS -29.65
  - FLUKA 28.69
**IMC – Lateral Deposition by electron**

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**All $e^-$ @ 1 TeV**

**All $e^-$ @ 10 TeV**

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**IMC Lateral Distribution**

**Results:**
- Higher the energy higher the difference at centre (0 - 20%)
- Discrepancies in the low energy tails (FLUKA: 20 - 60%; EPICS: 45 - 75%)

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Difference calculated as:

\[
\text{Diff} = \frac{\text{Epics}}{G4} - 1
\]

\[
\text{Diff} = \frac{\text{Fluka}}{G4} - 1
\]
IMC - Longitudinal Deposition by electron

All $e^-$ @ 1 TeV

All $e^-$ @ 10 TeV

Difference calculated as:

$$\text{Diff} = \frac{\text{Epics}}{\text{G4}} - 1$$

$$\text{Diff} = \frac{\text{Fluka}}{\text{G4}} - 1$$

**IMC Longitudinal Distribution Results:**
- Increasing trend for EPICS with more discrepancies at 10 TeV (max: -40%)
- Constant trend for FLUKA with more discrepancies at 10 TeV (+40%)
CHD - Total Energy Deposition by electron

<table>
<thead>
<tr>
<th>CHD</th>
<th>Simulation</th>
<th>BinMax Diff. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEANT4</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>EPICS</td>
<td>-9.749</td>
<td></td>
</tr>
<tr>
<td>FLUKA</td>
<td>-2.141</td>
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<tr>
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<th>Simulation</th>
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</tr>
</thead>
<tbody>
<tr>
<td>GEANT4</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>EPICS</td>
<td>-9.517</td>
<td></td>
</tr>
<tr>
<td>FLUKA</td>
<td>-3.348</td>
<td></td>
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</table>

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>GEANT4</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>EPICS</td>
<td>-31.56</td>
<td></td>
</tr>
<tr>
<td>FLUKA</td>
<td>5.004</td>
<td></td>
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</tbody>
</table>

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>GEANT4</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>EPICS</td>
<td>-41.92</td>
<td></td>
</tr>
<tr>
<td>FLUKA</td>
<td>28.33</td>
<td></td>
</tr>
</tbody>
</table>
PROTONS
Proton Benchmark

- The Tasc total energy distribution are in good agreement at all energies tested

- Large discrepancies between G4/FLUKA and EPICS for IMC and CHD, especially for triggered particles. With respect to electrons, here the agreement between G4 and FLUKA is good at all the energies.

- I'm going to show the distributions for TASC, IMC and CHD underlining the discrepancies.
TASC – Total Energy Deposition by proton

**HE Trigger Efficiency**

@ 1 TeV:
- GEANT4: 20.60%
- EPICS: 19.62%
- FLUKA: 20.33%

@ 100 GeV:
- GEANT4: 15.58%
- EPICS: 15.94%
- FLUKA: 16.47%

@ 10 GeV:
- GEANT4: 3.41%
- EPICS: 1.70%
- FLUKA: 2.11%

@ 10 TeV:
- GEANT4: 32.21%
- EPICS: 26.18%
- FLUKA: 28.15%

**HE Trigger Efficiency**

@ 10 TeV:
- GEANT4: 3.41%
- EPICS: 1.70%
- FLUKA: 2.11%

@ 100 GeV:
- GEANT4: 15.58%
- EPICS: 15.94%
- FLUKA: 16.47%

@ 10 GeV:
- GEANT4: 3.41%
- EPICS: 1.70%
- FLUKA: 2.11%

@ 1 TeV:
- GEANT4: 20.60%
- EPICS: 19.62%
- FLUKA: 20.33%

**Simulation BinMax Diff. (%)**

@ 10 GeV:
- GEANT4: 0
- EPICS: -19.05
- FLUKA: -1.907

@ 100 GeV:
- GEANT4: 0
- EPICS: -0.000267
- FLUKA: 9.409

@ 10 TeV:
- GEANT4: 0
- EPICS: -13.69
- FLUKA: -16.43
## IMC - Total Energy Deposition by proton

### HET p @ 10 GeV

<table>
<thead>
<tr>
<th>Simulation</th>
<th>BinMax Diff. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEANT4</td>
<td>0</td>
</tr>
<tr>
<td>EPICS</td>
<td>17.75</td>
</tr>
<tr>
<td>FLUKA</td>
<td>-10.55</td>
</tr>
</tbody>
</table>

### HET p @ 100 GeV

<table>
<thead>
<tr>
<th>Simulation</th>
<th>BinMax Diff. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEANT4</td>
<td>0</td>
</tr>
<tr>
<td>EPICS</td>
<td>-62.42</td>
</tr>
<tr>
<td>FLUKA</td>
<td>-15.91</td>
</tr>
</tbody>
</table>

### HET p @ 1 TeV

<table>
<thead>
<tr>
<th>Simulation</th>
<th>BinMax Diff. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEANT4</td>
<td>0</td>
</tr>
<tr>
<td>EPICS</td>
<td>-80.55</td>
</tr>
<tr>
<td>FLUKA</td>
<td>-9.92</td>
</tr>
</tbody>
</table>

### HET p @ 10 TeV

<table>
<thead>
<tr>
<th>Simulation</th>
<th>BinMax Diff. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEANT4</td>
<td>0</td>
</tr>
<tr>
<td>EPICS</td>
<td>-78.53</td>
</tr>
<tr>
<td>FLUKA</td>
<td>18.17</td>
</tr>
</tbody>
</table>
**Discrepancies in the low energy tails** (FLUKA: 20%; EPICS: 85 - 95 %)

**Constant trend** for FLUKA wrt G4

**Epics systematically lower than G4**

Difference calculated as:

\[
\text{Diff}_{\text{EPICS}} = \frac{\text{Epics}}{\text{G4}} - 1
\]

\[
\text{Diff}_{\text{FLUKA}} = \frac{\text{Fluka}}{\text{G4}} - 1
\]
IMC - Longitudinal distributions by proton

**All p @ 1 TeV**

**All p @ 10 TeV**

- **Constant trend for FLUKA wrt G4 (< -15%)**
- **Increasing trend for EPICS wrt G4, more discrepancies at 10 TeV (max -70%)**

Difference calculated as:

\[
\text{Diff} = \frac{\text{Epics}}{\text{G4}} - 1
\]

\[
\text{Diff} = \frac{\text{Fluka}}{\text{G4}} - 1
\]
CHD - Total Energy Deposition by proton

HET p @ 10 GeV

10 GeV

Simulation  BinMax Diff. (%)
GEANT4       0
EPICS       -65.16
FLUKA       -27.07

100 GeV

Simulation  BinMax Diff. (%)
GEANT4       0
EPICS       -79.31
FLUKA       -14.32

1 TeV

Simulation  BinMax Diff. (%)
GEANT4       0
EPICS       -82.99
FLUKA       -1.179

10 TeV

Simulation  BinMax Diff. (%)
GEANT4       0
EPICS       -82.12
FLUKA       0.3576
SUMMARY PLOTS
IMC → Large Differences in the shape of the distributions for Epics wrt GEANT 4 → since this behaviour is present also in cad model (see Lorenzo's presentation) we can exclude a geometry problem.

To be understood the anomalous behaviour of FLUKA wrt G4 above 1TeV.
CHD → Large Differences in the shape of the distributions for Epics wrt GEANT 4 → since this behaviour is present also in cad model (see Lorenzo's presentation) we can exclude a geometry problem.

To be understood the anomalous behaviour of FLUKA wrt G4 above 1TeV.
IMC → Large differences in the shapes of distributions for EPICS wrt GEANT4 → since this behaviour is present also in cad model (see Lorenzo's presentation) we can exclude a geometry problem.
CHD → Large differences in the shapes of distributions for EPICS wrt GEANT4 → since this behaviour is present also in cad model (see Lorenzo's presentation) we can exclude a geometry problem.
CONCLUSIONS

• Pisa model simulations show good agreement for TASC both for electrons and protons.

• Epics has a different behaviour in IMC and CHD both for protons and electrons even using the simplified Pisa model, which has exactly the same geometry for the three simulations.

• It seems that the observed discrepancies are due to differences in the physical models/processes implemented by the simulations.

• Still to be studied and understood is the anomalous behaviour of FLUKA with respect to GEANT 4 for 10 TeV electrons.
THANK YOU!